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Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

1. Your reference — XLT 102

2. Patent application number (The Patent Office will fill in this part) — 0410906.2 — 14 MAY 2004

3. Full name, address and postcode of the or of each applicant (underline all surnames)

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419 31ST AVENUE
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BP EXPLORATION OPERATING COMPANY LTD.
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EC2M 7BA

Patents ADP number (if you know it) — 8778144001 — 6225916002

If the applicant is a corporate body, give the country/state of its incorporation — USA — UNITED KINGDOM

4. Title of the invention

NON-THREADED EXPANDABLE PIPE CONNECTION SYSTEM

5. Name of your agent (if you have one)

"Address for service" in the United Kingdom to which all correspondence should be sent (including the postcode)

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6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and (if you know it) the or each application number

Country	Priority application number (if you know it)	Date of filing (day / month / year)
GB	0329811.4	24/12/03

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing (day / month / year)

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? (Answer 'Yes' if:
   a) any applicant named in part 3 is not an inventor, or
   b) there is an inventor who is not named as an applicant, or
   c) any named applicant is a corporate body.
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YES

9. Accompanying documents: A patent application must include a description of the invention. Not counting duplicates, please enter the number of pages of each item accompanying this form:

Continuation sheets of this form	—
Description	12 —
Claim(s)	—
Abstract	—
Drawing(s)	15 + 15 [illegible]

10. If you are also filing any of the following, state how many against each item.

Priority documents	—
Translations of priority documents	—
Statement of inventorship and right to grant of a patent (Patents Form 7/77)	—
Request for a preliminary examination and search (Patents Form 9/77)	—
Request for a substantive examination (Patents Form 10/77)	—
Any other documents (please specify)	—

11. I/We request the grant of a patent on the basis of this application.

Signature(s) Milgate Patent Services Date 12/5/04

12. Name, daytime telephone number and e-mail address, if any, of person to contact in the United Kingdom PAUL HARMAN 020 7704 9997

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Notes

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Non-threaded expandable pipe connection system

The present invention relates generally to the connection of piping used on oil and gas wells which can be short joints of steel tube 30-40ft long, or sand screens of similar length, or coiled tubing which generally requires only one method of connection which is at it lower most end.

Traditionally, the oil industry assembles the casing which lines the well, or the drillpipe used to create the well, or completion tubing used to produce the well, using short sections of tubes which have a pin down – box up configuration. Numerous threads have been developed and used, ranging from low cost tapered round thread, stub acme, multi-stepped, and sealing systems, and from face seals to elastomer O-ring or metal to metal seal arrangements.

With the tendency within the industry to deploy and expand casing or sand screens in the well, it has become extremely challenging for the tool joint designers to make a threaded tool joint which can tolerate torque, high tensile loads, be gas tight and expand when deployed in the well from as little as 5% to as much as 50%.

It is an objective of this invention to provide a convenient method and apparatus of connecting adjacent sections.

According to the present invention, there is provided a connection between two adjacent generally tubular sections, wherein an expandable element is included which seals the assembly without requiring the assembly to rotated. The connectors may be expanded at the surface, or expanded downhole.

According to another aspect of the present invention, two sections are brought together to form a coupling, and the inner surface expanded to form an interference fit. A partial expansion of this connector may be done at the factory or at the rig floor and then fully expanded downhole as required.

According to another aspect of the present invention, two sections are brought together to form an interference fit, the surface of at least one of the interference faces is treated by one or more of the following processes; (i) by plasma spraying soft metals to enhance the metal to metal seal face, (ii) by plasma spraying hard angular material to significantly increase the surface friction and/or (iii) by depositing elastomer for comprehensive connection sealing.

According to another aspect of the present invention, a stepped connection profile is provided on at least one of the adjacent sections to be joined to maximize the ultimate tensile strength for a flush jointed connection.

According to another aspect of the present invention, the two tubes are gripped either internally, externally or a combination of the two.

According to another aspect of the present invention, a joint and a method of joining are provided wherein there is included a helical spring and/or longitudinal members between the interface of the adjacent sections. This enhances the torque and tensile load capability.

According to another aspect of the present invention, there is provided an apparatus and method for swaging the inner diameter of a tubular member, including the steps of outwardly displacing swaging elements, rotating the apparatus, and axially displacing said apparatus. In this manner a helical

swage can be generated. Ideally, this method can be employed for joining two adjacent tubular sections together.

According to another aspect of the present invention, projecting elements are provided on or both of the sections, so that the section may be expanded, the outer section reduced, or both, to securely engage the sections. Such projecting elements may be formed by plasma spraying a tube to form raised portions. Preferably the end of the section also includes a smooth or polished section to form a metal-to-metal seal.

It will be seen that these arrangements allow a conventionally machined thread form box and pin connection system to be eliminated.

Embodiments of this invention will now be described by way of example with reference to the following drawings.

Figure 1 shows an external side view of a flush jointed pin end of an embodiment of this invention.

Figure 2 shows a section view of the same flush jointed connector with a swaging tool part assembled.

Figure 3 shows the same view as figure 2 with the swaging tool fully assembled.

Figure 4 shows the same view as figure 3 with the swaging tool pulled back in to snugly fit to the surface to be swaged on the pin end.

Figure 5 shows the same view as figure 4 with the pin end and swaging tool assembly being lowered into the flush jointed box end of the tool connection.

Figure 6 shows the pin and box fully engaged and temporarily clamped together using an external C clamp.

Figure 7 shows the same view as figure 6 with the swaging tool being energized hydraulically, drawing the swaging die through the section to be expanded.

Figure 8 shows the surface swaging operation completed, the pin and box fully engaged, a flush ID and the swaging tool being recovered through the ID of the upper tube.

Figure 9 shows a schematic of the overall layout of the equipment on the rig floor.

Figure 10 shows a schematic of the overall equipment for a CT applied device.

Figure 11 shows another embodiment of the coupling using an internal upset segment.

Figure 12a shows the embodiment in figure 11, fully swaged.

Figure 12b shows another embodiment of the coupling.

Figure 13 shows another embodiment of the coupling using an external upset segment.

Figure 14 shows the embodiment in figure 13, swaged.

Figure 15 shows another embodiment of the coupling using both internal and external upset segments.

Figure 16 shows the embodiment in figure 15, swaged.

Figure 17 shows another embodiment of the coupling using an internal upset segment with a helical thread insert used to enhance the tensile load capability.

Figure 18 shows the embodiment in figure 17, swaged.

Figure 19 shows another embodiment of the coupling using both internal and external upset segments with longitudinal segments used to increase the torque carrying capability.

Figure 20 shows a cross sectional view of the embodiment in figure 19, swaged.

Figure 21 shows a side view of an over coupling protector, an external cable and two tubes prior to the swaging process.

Figure 22 shows the same view as figure 21 after swaging.

Figure 23 shows a section view YY of figure 21

Figure 24 shows a section view ZZ of figure 22

Figure 25 is a section side view of an embodiment of the connector applied to sand screens.

Figure 26 is a side view of a ball bearing roller expander in its undeployed mode.

Figure 27 is a side view of a ball bearing roller expander in its deployed (expanding) mode

Figure 28 is the roller expander in operation down the well

Figure 29 is a section of casing expanded, and its characteristic corrugated profile.

Figure 30 is a side view of a reduced tube end with plasma sprayed dimples in its external surface

Figure 31 is a section AA view of figure 30

Figure 32 is detail B of figure 31

Figure 33 is a section side view DD of figure 34, and shows the inner tube has been expanded into the ID of a larger diameter pipe.

Figure 34 shows a side view of the inner tube with plasma sprayed hard coating dimples sprayed on it expanded into the ID of a larger diameter tube (the outer surface has been removed for clarity)

Figure 35 shows the end view of the expanded inner pipe in the larger ID outer pipe

Referring to figure 1, a flush jointed embodiment of the invention is swaged together. A tube 1 has a stepped lower end profile 2. This profile provides a tapered fit, and increases the ultimate tensile strength of the flush jointed connection to close to that of the tensile strength of the virgin pipe. The surfaces of each of the steps may or may not be treated. To enhance the surface friction a plasma-sprayed, rough, hard material such as tungsten 4 can be deposited. Alternatively, a soft metal layer 5 could be deposited on one of the stepped layers to enhance the metal to metal sealing capability, again using plasma spraying; this layer may be a tin, copper or other soft metal deposit. A thin elastomer 3 may also be used.

Referring to figure 9, a section of pipe is picked up using a conventional traveling block arrangement 6, during this operation a swaging tool 7 is lowered down the pipe's internal diameter using an umbilical 8 and winch 9. Referring to figure 2, the lower end 10 of power section of the tool extends from of the lower end 11 of the tube 1. When sufficiently exposed the swaging die head 12 is attached to 10 using pin 13 as shown in Figure 3. This assembly is then pulled up to a snug contact with the face to be expanded 14 as shown in figure 4. The assembly can then be stabbed into the flush jointed box 15 as shown in figure 5, until the faces of the box and pin come together 16 as shown in figure 6. The box 15 has a stepped profile 2' corresponding to that of pin stepped profile 2. A clamp 17 can

then be installed, which locates in grooves 18 and 19 on the box and pin and temporarily holds the connection together while the swaging operation is being performed. Referring to figure 7, hydraulic pressure is applied down control line 20, energising piston 21 forcing it downwards. A series of balls 22 are trapped against the piston's tapered surfaces 25, and the piston's downward actions forces these balls 22 radially outwards, firmly gripping the inner surface of the tube 1. The balls do not mechanically score or damage the inner surface of the tube 1. The same hydraulic pressure energises seal 23 which urges the piston body 30 upwardly away from the anchored balls 22. The swaging head 12 is attached to the piston body 30, so as it is forced upwards the swaging head 12 expands the inner surface 31 of the pin connection. Referring to figure 8, on completion of the piston stoke hydraulic pressure drops off providing indication to the operator that the swaging is completed. There is a slight recovery of the strain, but a visible increase in the external diameter in this embodiment is evident 31 and can be measured for quality assurance.

As the traveling blocks 6 lower the tubing into the well, the umbilical 8 and swaging tool 7 are winched out of the top 32 of the tubing currently being lowered into the well, and are then ready to be lowered into the next tubing section to be picked up and connected to the tubing in the well.

Figure 10 shows the assembly process (in particular a swaging tool) being applied to the lower end of a coiled tubing string, typically at a well surface.

Referring to figure 11 and 12a, two tubes 41 and 42 are pushed together onto a double male adaptor 43. The internal surface 44 is swaged radially outwards using a swaging tool which results in an expanded internal diameter 45 of the adaptor 43. The internal taper 46 creates a smooth

external increase in diameter 47 along the length of the tubes. The final result is an external upset interference fit coupling. The function of the mid way lug on the adaptor 43 is to hold the pipes in the correct position relative to the adaptor. The lug could be the same OD as the pipe 41 and 42. The connector many be partially expanded at surface to meet the required tensile and torque loads and then run in hole and then be fully swaged as required.

Referring to figure 12b, rather than the middle section of the adapter being being uniform as shown in figures 11 and 12a, the adaptor's middle section's OD may be tapered 48 towards the mid point as shown (the distal sections of the adapter still being tapered to the upper and lower ends respectively), so that it would have sufficient clearance during the installation, but once expanded it will be effectively trapped, increasing its pull out resistance and requiring even greater overpull to pull it free.

Referring to figure 13 and 14 there is shown a further embodiment of the invention, two tubes 41 and 42 are pushed together into a double female adaptor 50. The internal surface is expanded using a roller swaging tool, resulting in a corrugated expanded profile 51 in the flush internal diameter of tubes 41 and 42 adjacent to the adaptor 50. The external diameter of the adaptor is expanded from its original diameter to a larger diameter, recovering slightly after the expanding tool has completed its pass. The corrugations 51 are purposefully formed on the inside of the pipe by a rotating ball bearing swaging tool, the aim of these corrugations is to increase the collapse rating of the connector. In another embodiment of this invention these corrugations can be along the inner surface along the entire length of the pipe when in its final position downhole, to increase the collapse rating of the whole pipe.

Referring to figure 15 and 16 there is shown yet a further embodiment of the invention, two tubes 41 and 42 are pushed together, both on an internal adaptor 60 and an external adaptor 61. This provides increased surface area for torsional and tensile strength for the swaged connection.

Referring to figures 17 to 20 additional hardware could be used to increase the connections' torsional or tensile strength. One example of this a helical thread insert 70 (such as supplied under the name helicoil®) fitted on the external surface of male adaptor 71 and internal diameter of tubes 41 and 42. Advantageously, the helical insert has a diamond cross section as shown. When swaged the helical insert's profile causes it to embed itself into both surfaces 72, providing a connection similar to a thread form so increasing the tensile loading. For increased torsional strength, inserts 80 could be placed be placed between surfaces 81 and 82 and once the swaging operation has been completed, these become embedded and spline the adaptor 83 and tubes 41 and 42 together. Again, these inserts advantageously have a diamond cross section.

Referring to figures 21 and 24 in many cases cables and control lines have to be attached to the outside of the completion tubing. These can be expensive and time consuming components to assemble in their own right. This embodiment shows a simple over coupling protector which is shaped and energized by the swaging process. Once the two tubes 41 and 42 have been stabbed together a sheet steel wrap 90 is put around the coupling and power cable 91, both ends of the sheet steel wrap 90 are clipped together by interlinking the folded-over ends 92. This gives quite a snug fit prior to the swaging process. After the coupling has been swaged (or simultaneously with the coupling's swaging), the over-coupling protector 90 is itself expanded as shown at 93, so forming an ideal over-coupling protector for

the cable. This has two benefits; it holds the cable snug to the coupling, and because it clamps the cable firmly on both sides of the coupling it provides an ideal anchor to support the vertical load of the cable.

Figure 25 shows an internal 99 and external 100 connector which is perforated to enable flow to pass through its entire length, while being able to connect sections of sand screen 97, 98 together and support their tensile load.

Referring to figures 26 to 29 there is shown details and additional benefits from the ball bearing roller expander 104 as applied downhole. The tool 104 remains flush with, and can traverse along, the internal diameter of the pipe to any desired position. It can then be expanded to any required diameter by energizing a cone 101 which displaces ball bearing 102 mounted in arms 103, the amount the piston is displaced causing a proportional displacement of the ball bearing and hence the final expansion which will be achieved. The body 104 is rotated, whilst its axial motion 105 is also controlled, so that as the expansion process of the adjacent tube is carried out a helical corrugation 106 is generated. This process can be performed in or out of the well. This effect can be increased to create both corrugations on inside and outside surface of the expanded tube. This can both strengthen the thin wall tube which has been expanded and increase its collapse rating, or it can provide a ideal profile to locate additional support for the expanded thin wall tube.

Referring to figures 30 to 32, the tube end 110 has been reduced using conventional swaging dies. The nose has been left smooth 111 so that it can provide a metal to metal seal when expanded. A mask (not shown) is positioned over the remaining section of reduced end, the mask is a thin

aluminum metal sheet with holes uniformly distributed in it. The component is then plasma sprayed. Where there are holes, the plasma spray passes the mask and deposits and bonds to the base pipe. Plasma is the term for gas which has been raised to such a high temperature that it ionizes and becomes electrically conductive. When Plasma spraying, the plasma is created by an electric arc within the nozzle of the gun. The gas is formed into a plasma jet as it emerges from the gun nozzle. Powder particles are injected into this jet where they melt and then strike the surface being coated with high velocity. The mask is then removed from around the tube 110 and raised dimples 112 are left as shown. The dimples have a small step of hard material such as chromium or tungsten. When the tube is expanded the dimples embed themselves into the external coupling and form strong anchor points for tension, compression, torsion and bending resistance. Once this coupling is made it can never be broken.

Referring to figures 33 to 35 there is shown a liner hanger version of this tube to tube connection system. In this case dimples 112 are deposited on the outer surface of the inner tube 120, an expanding die is pushed in from the end 121 and it is expanded to bring the end 121 into intimate contact with the outer tube 122, a metal to metal pressure seal is formed in the smooth region 123 and the dimples 112 embed themselves into the inner surface of the outer tube 122 to form a secure anchor

Although only small amounts of expansion have been shown in these examples, the dimples can accommodate very large expansions of the base pipe, while performing all the tensile, compression, torsion and bending functions required.

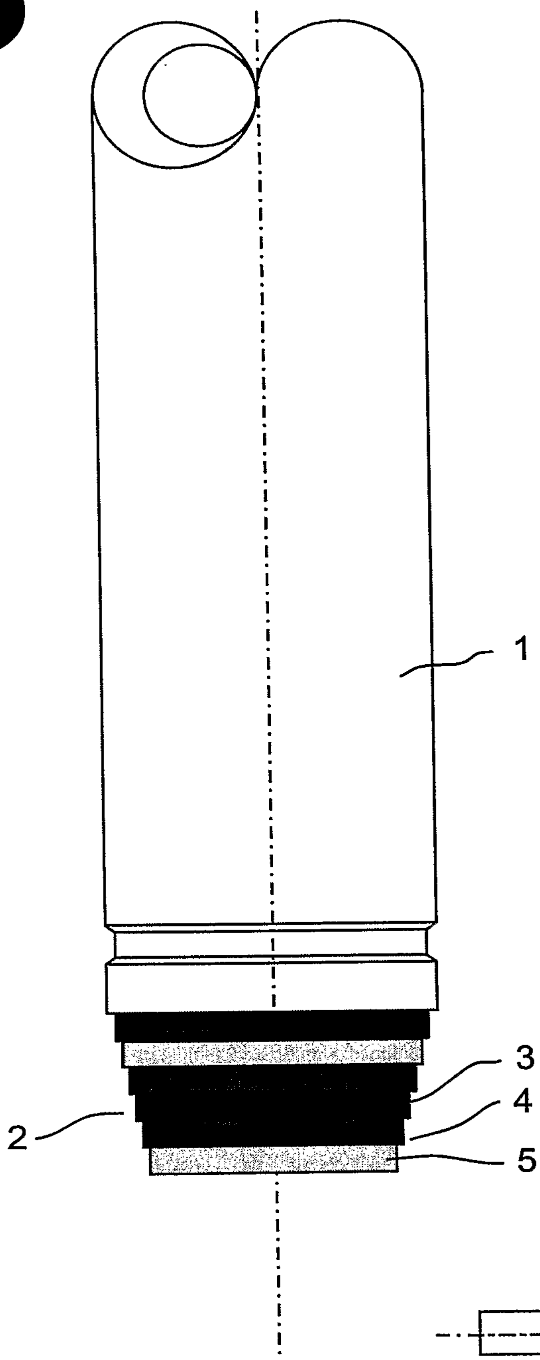


Figure 1

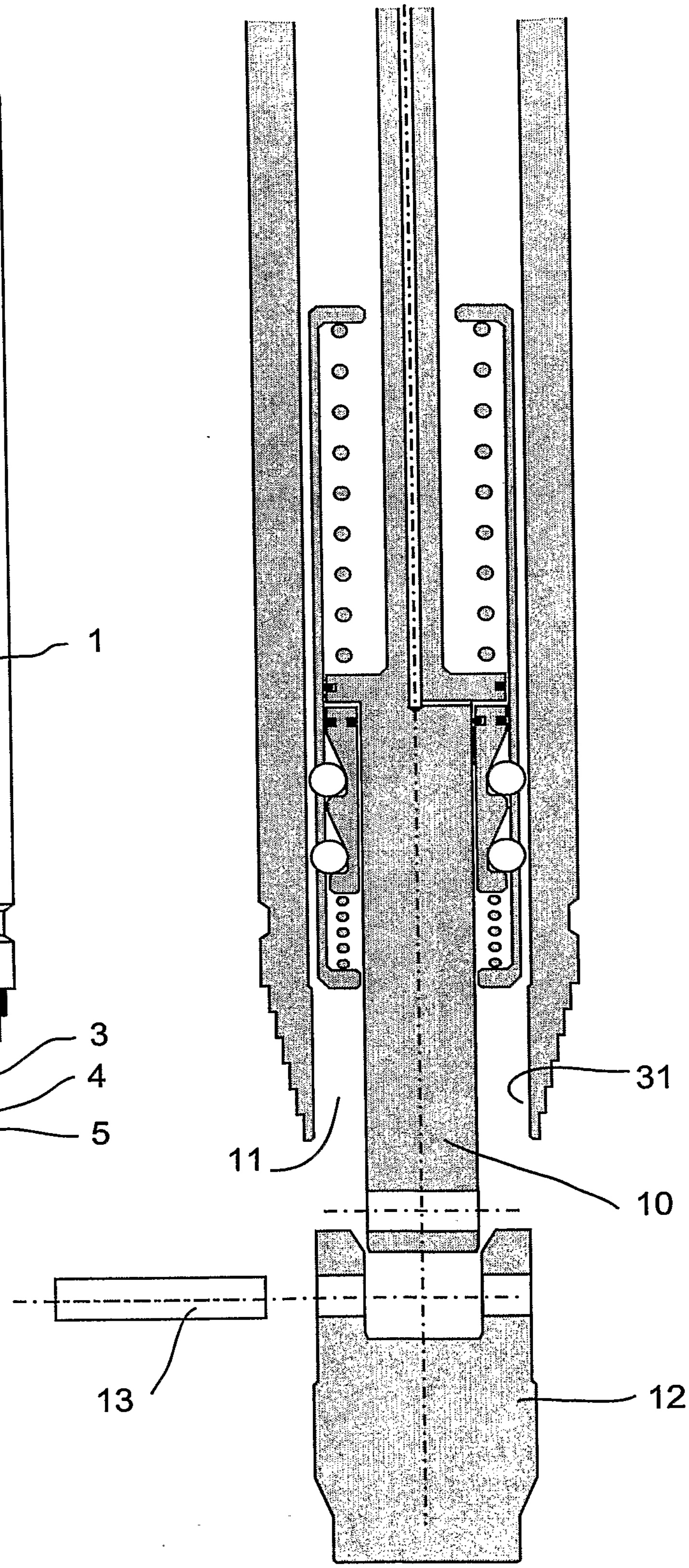


Figure 2

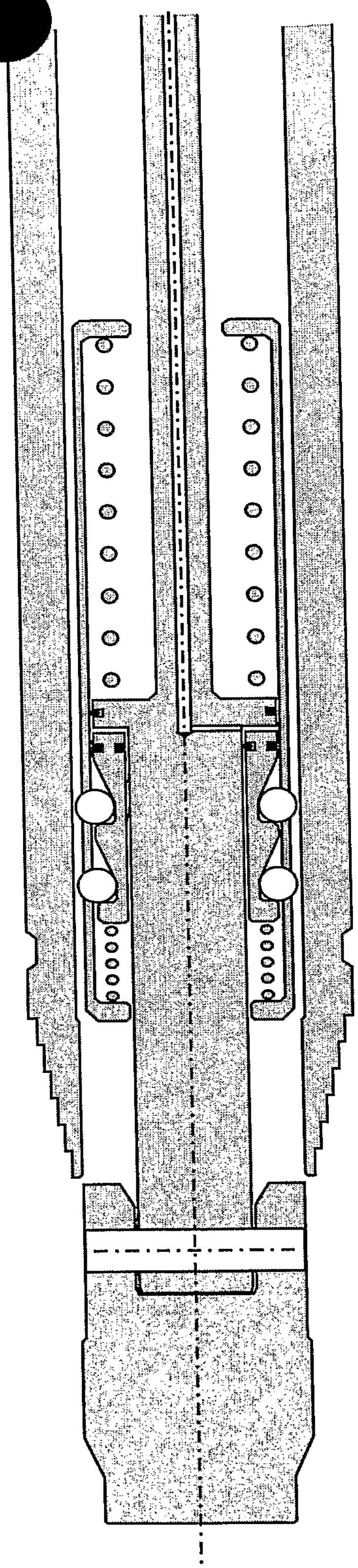
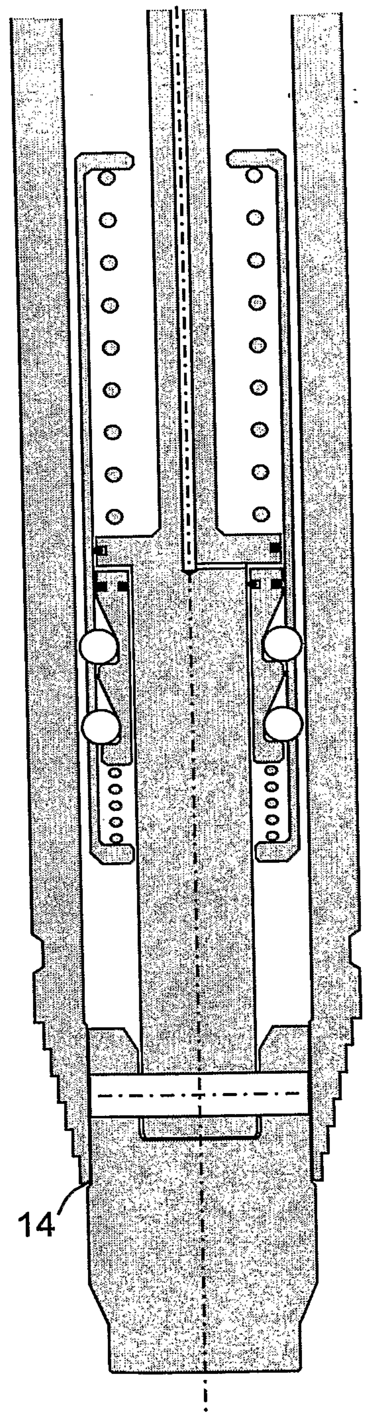


Figure 3



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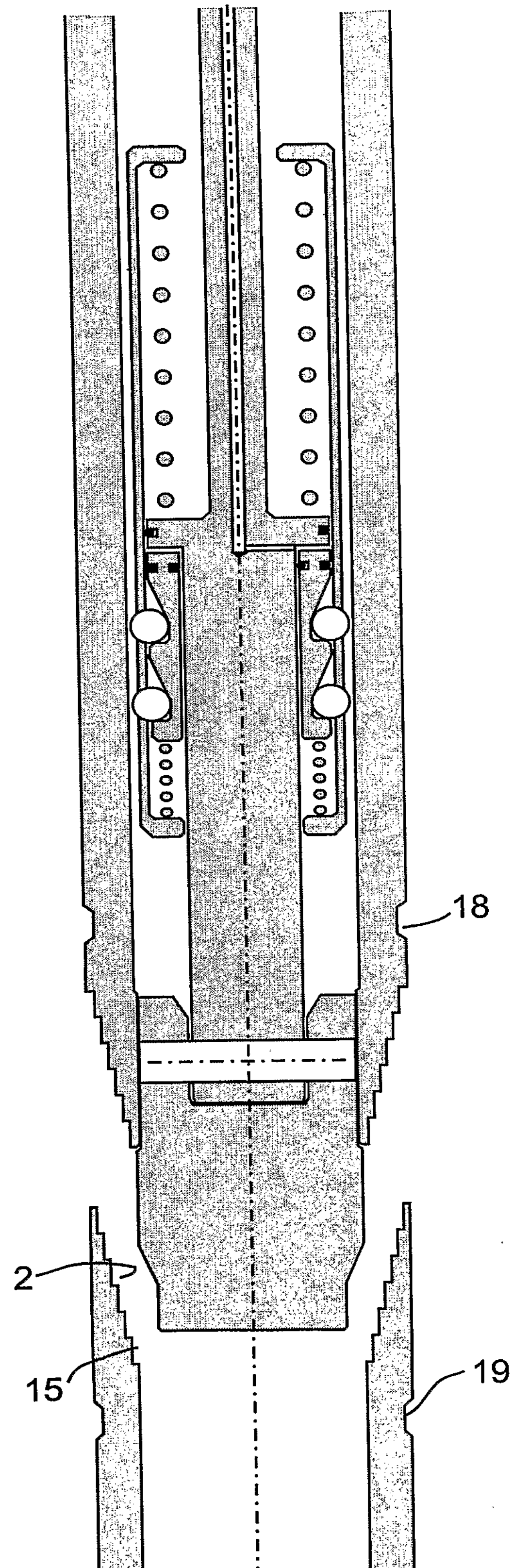


Figure 5

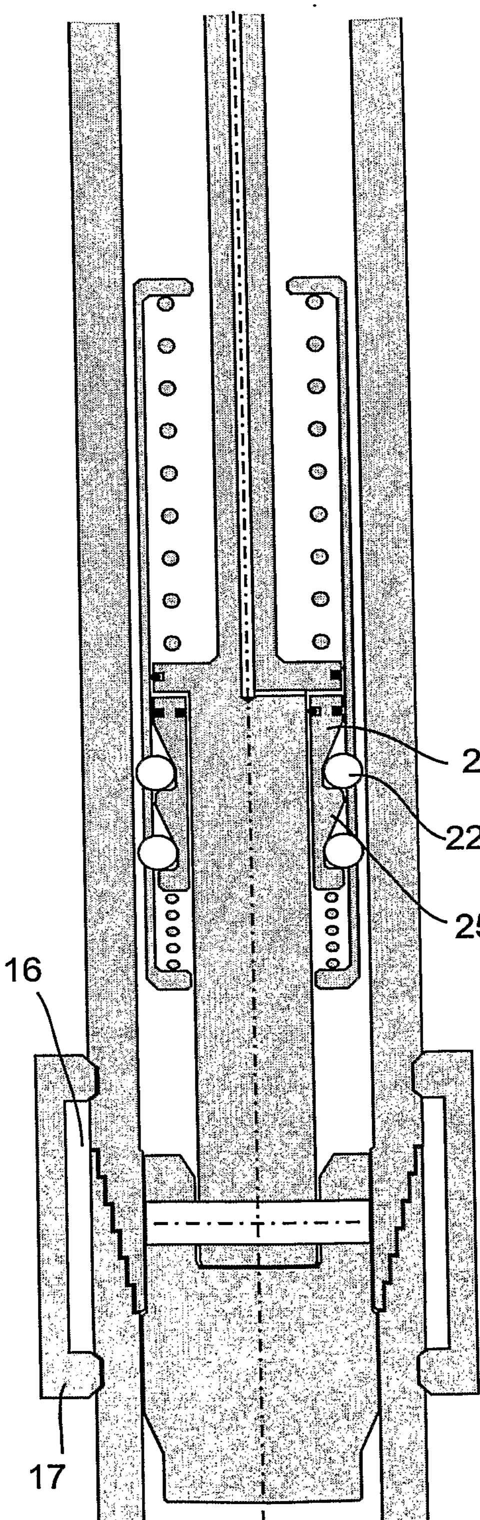


Figure 6

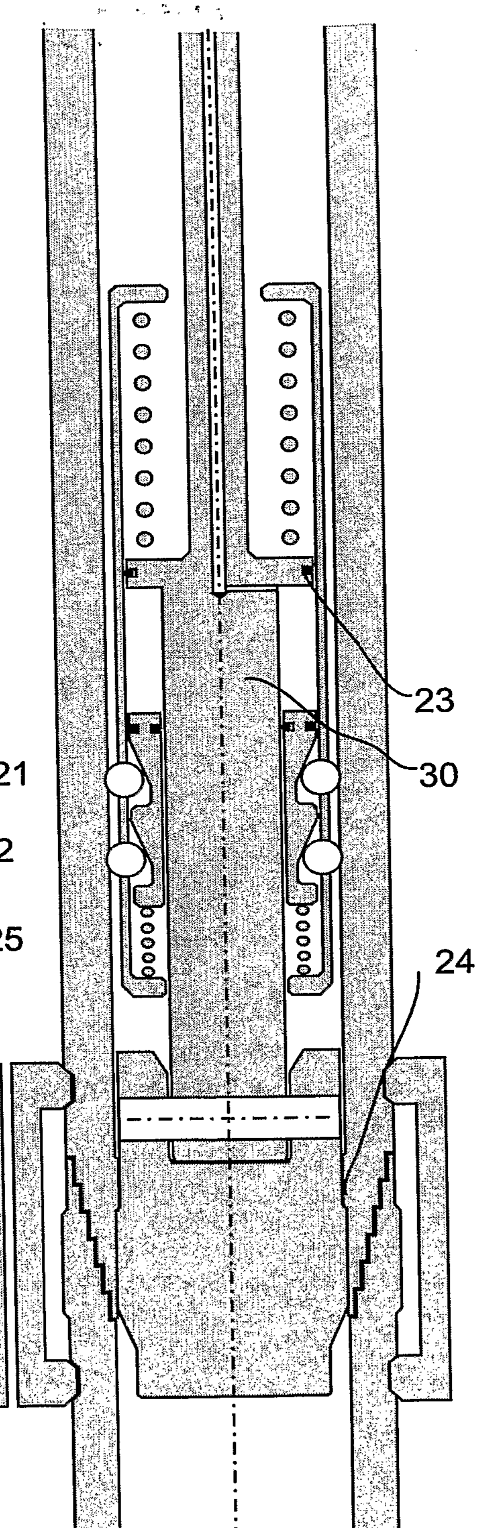


Figure 7

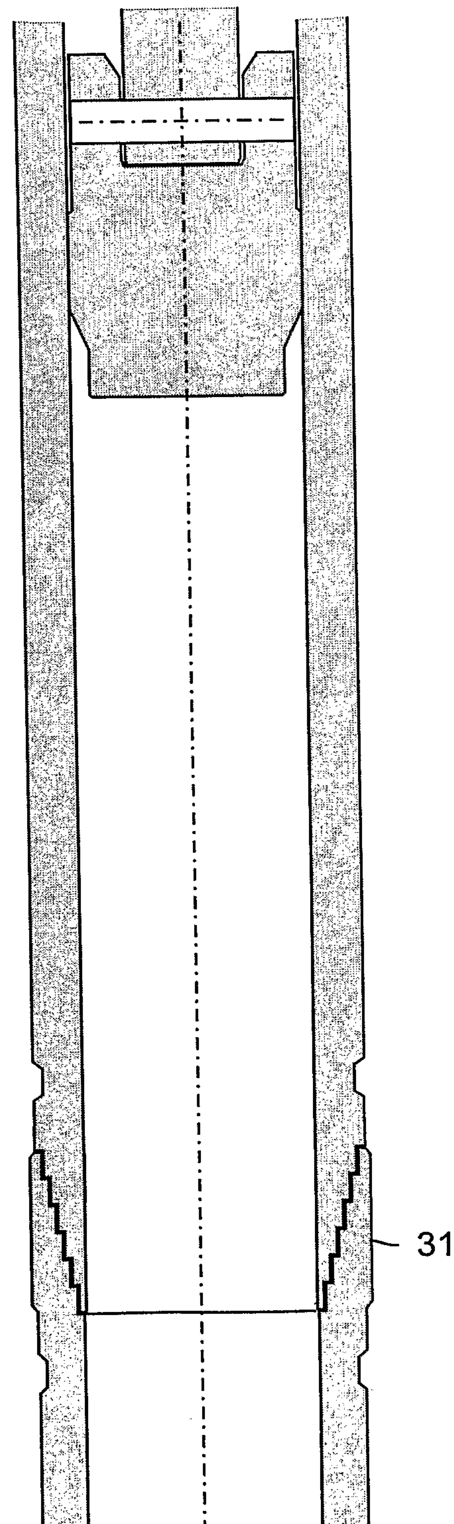


Figure 8

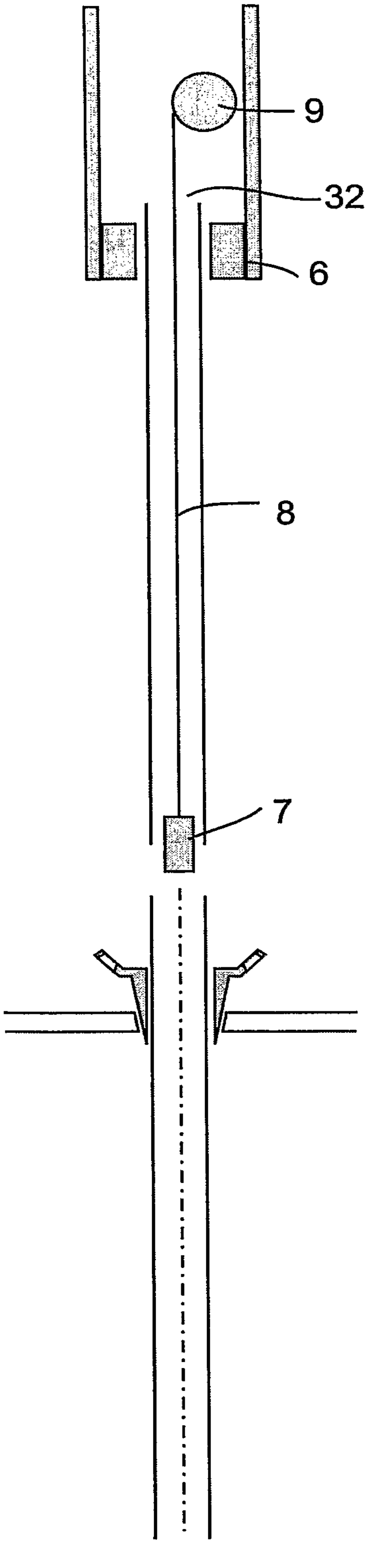
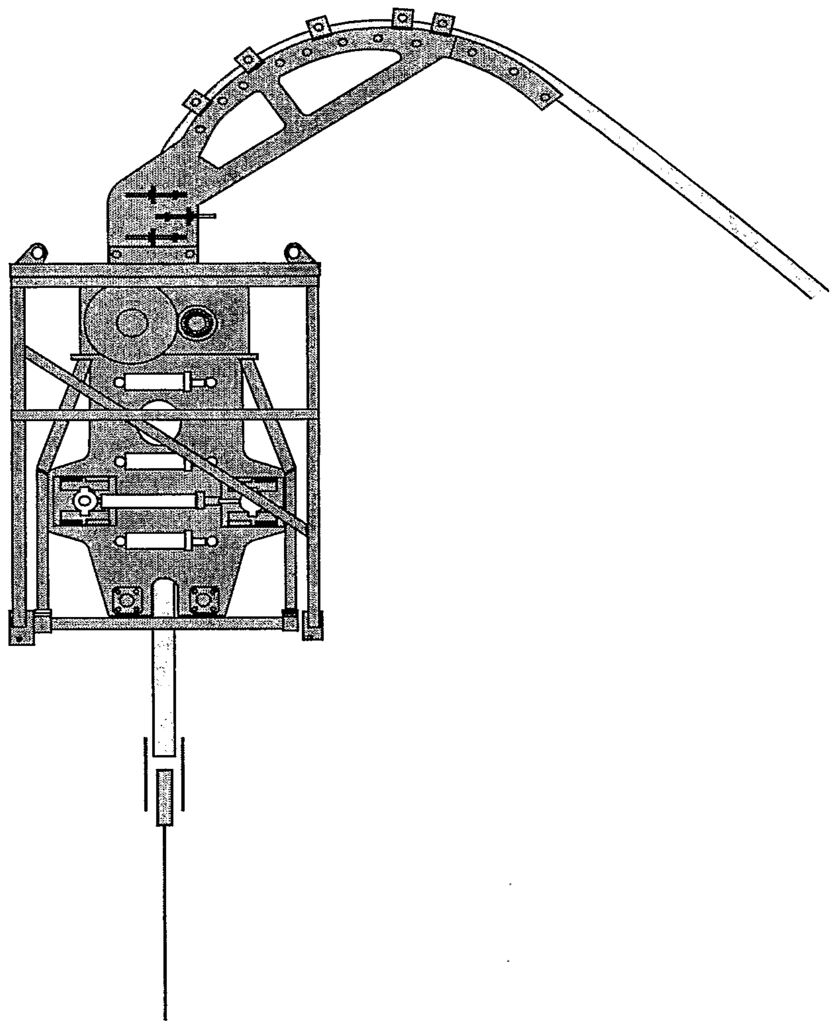


Figure 9



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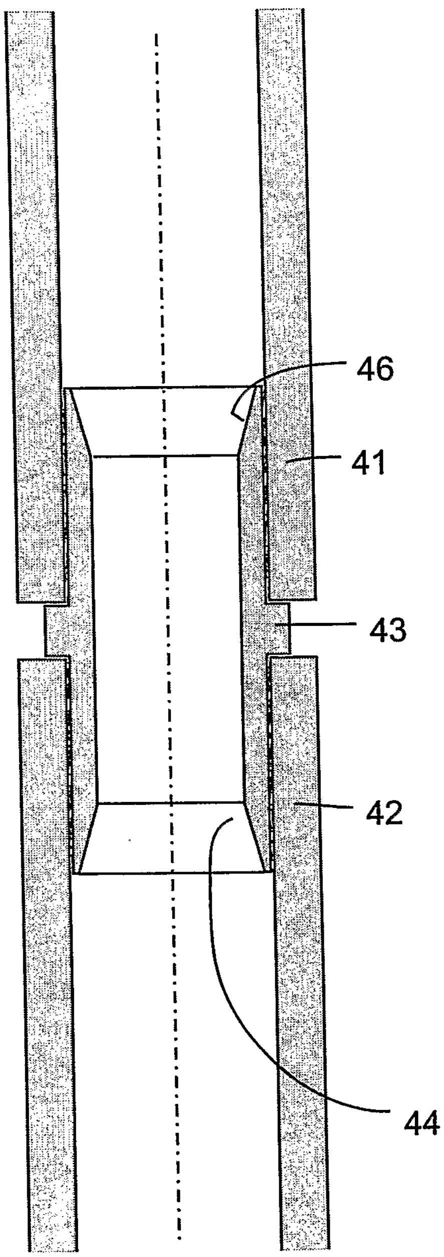

Figure 11

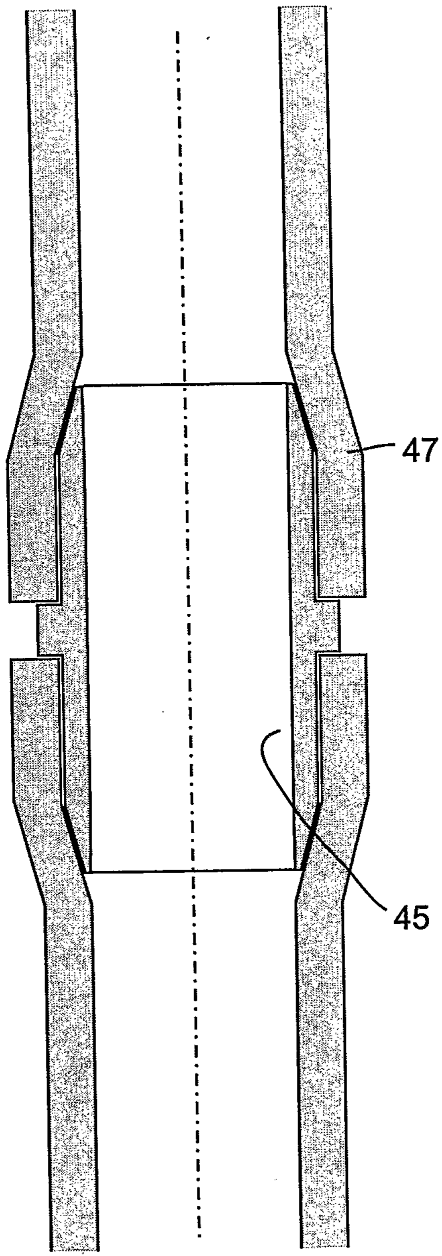

Figure 12a

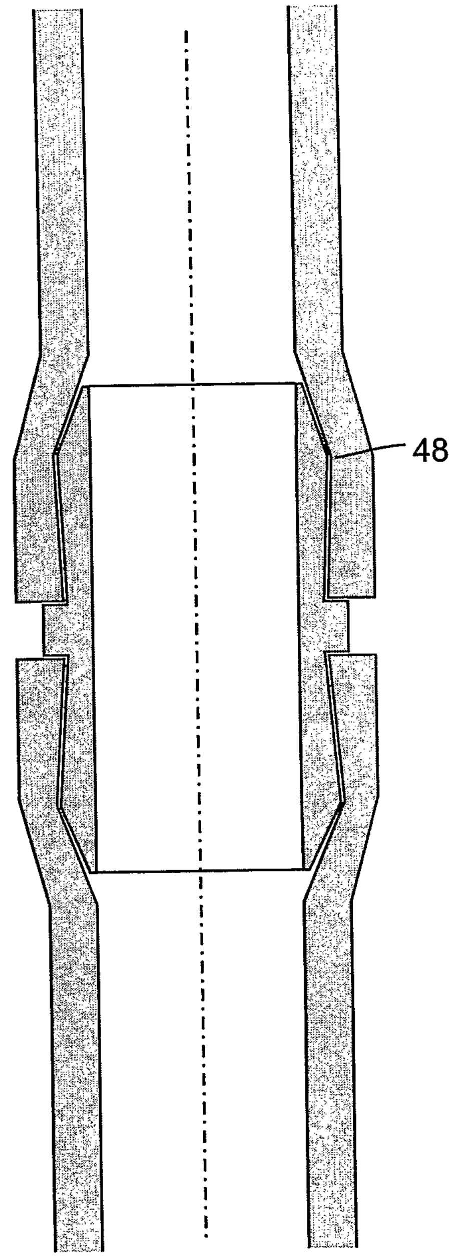

Figure 12b

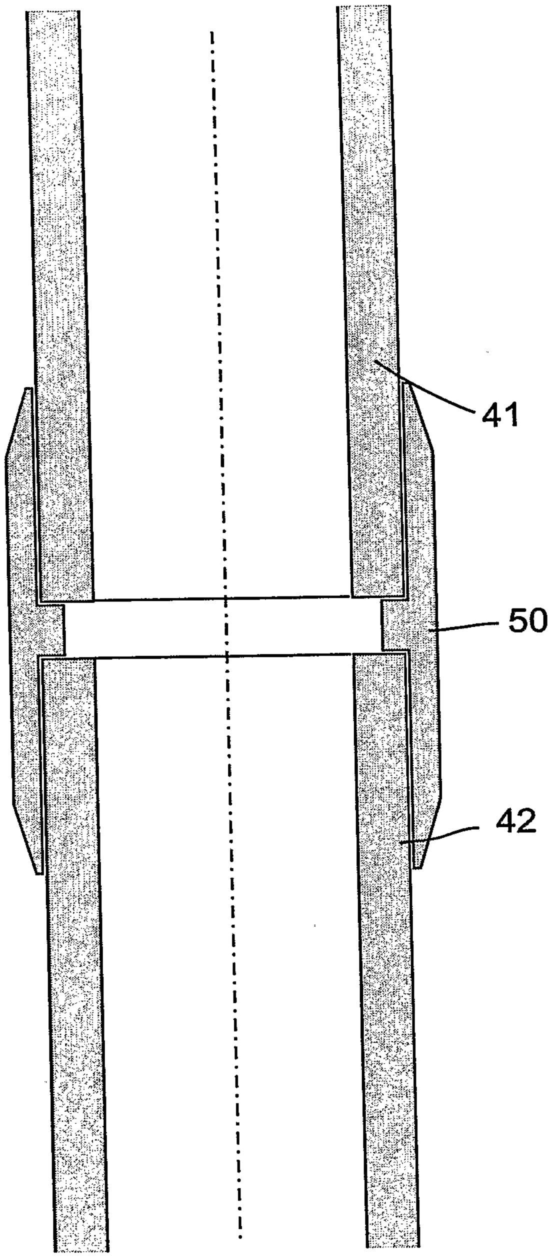

Figure 13

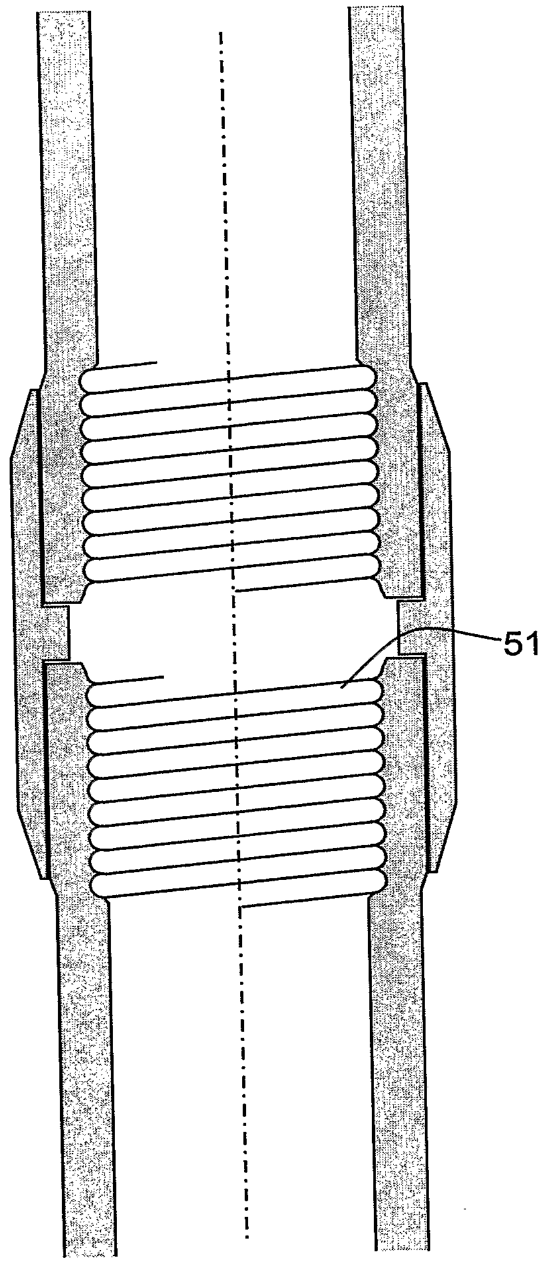

Figure 14

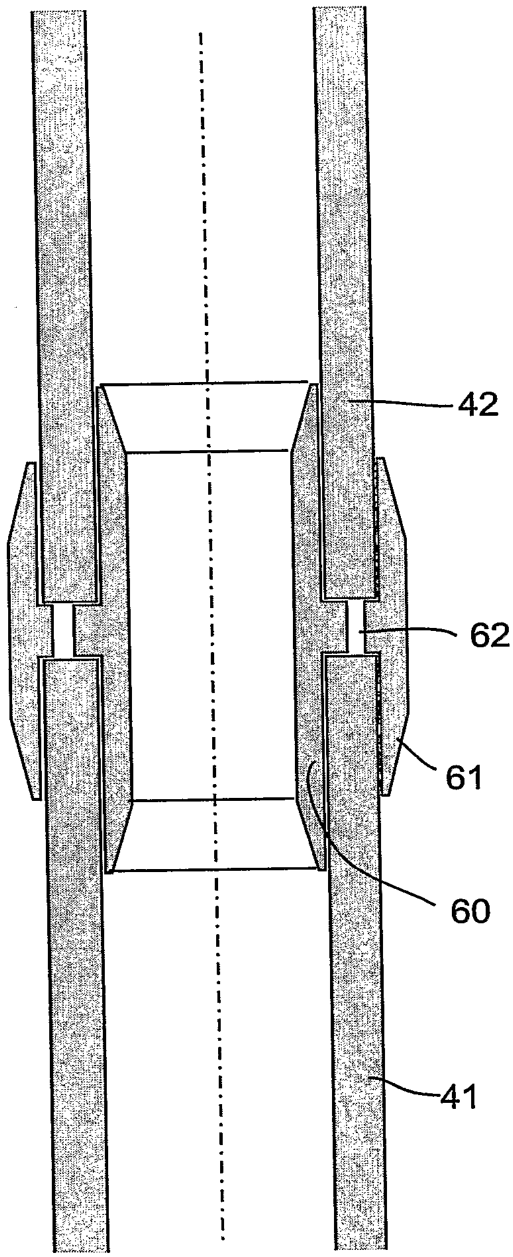

Figure 15

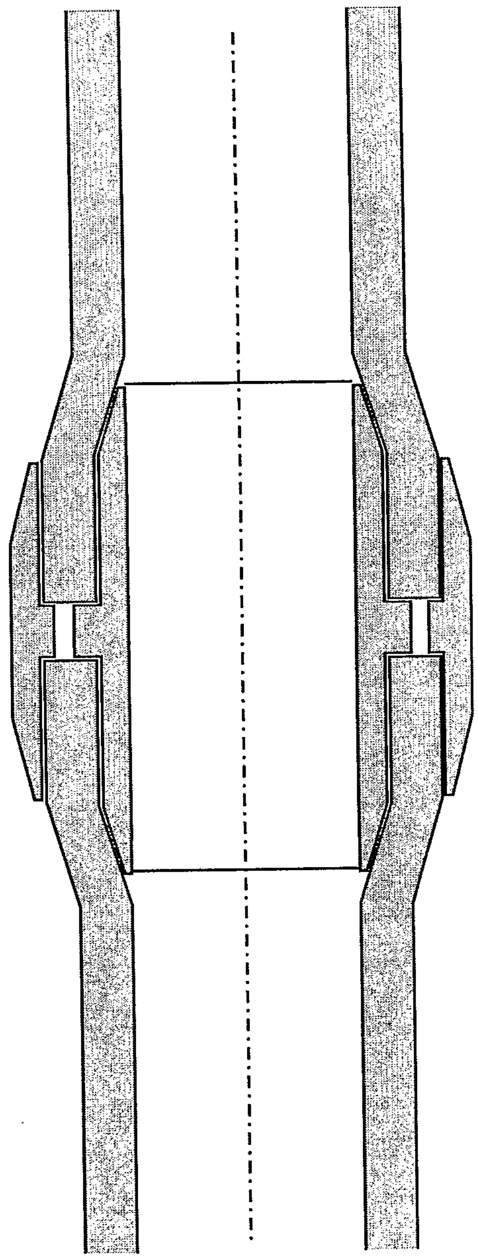

Figure 16

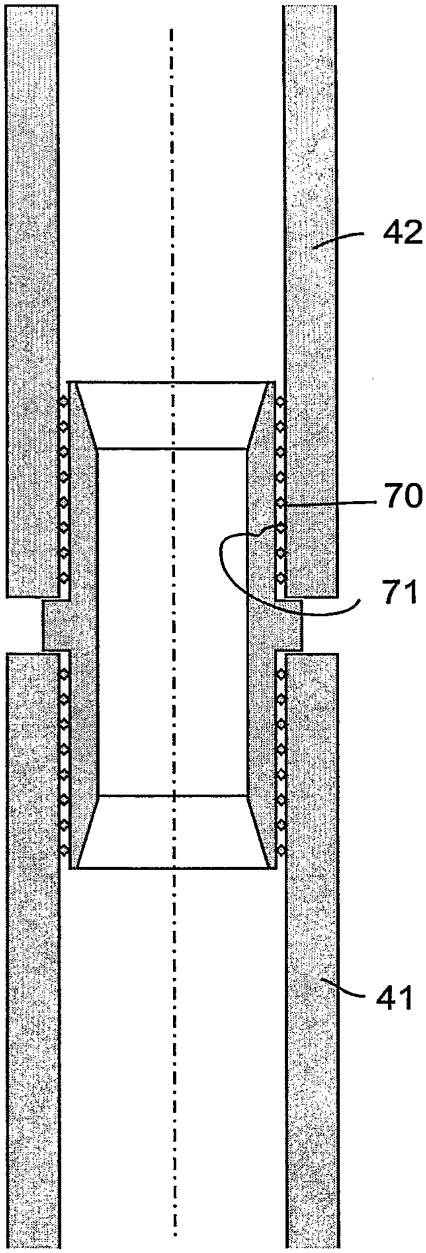

Figure 17

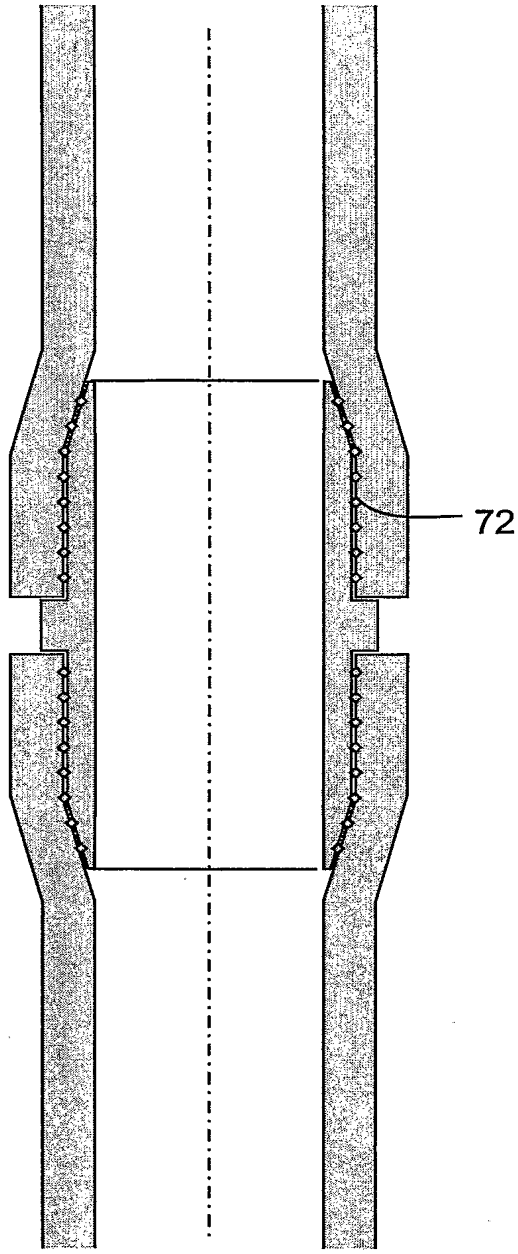

Figure 18

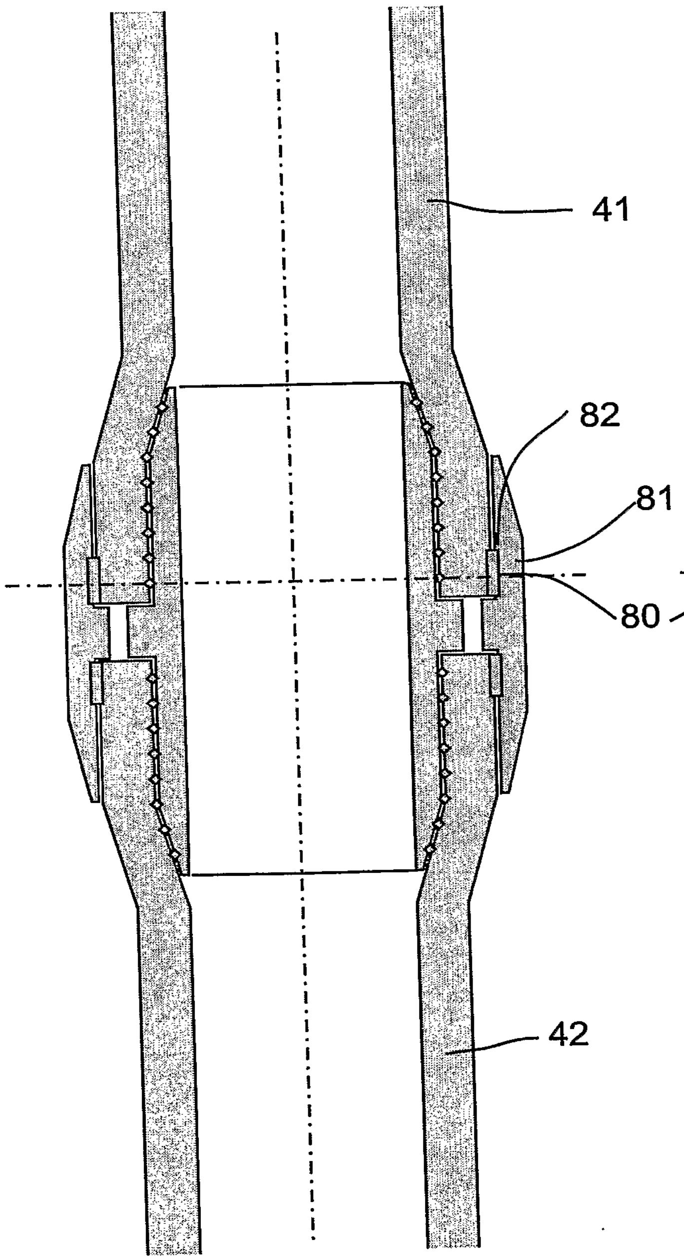

Figure 19

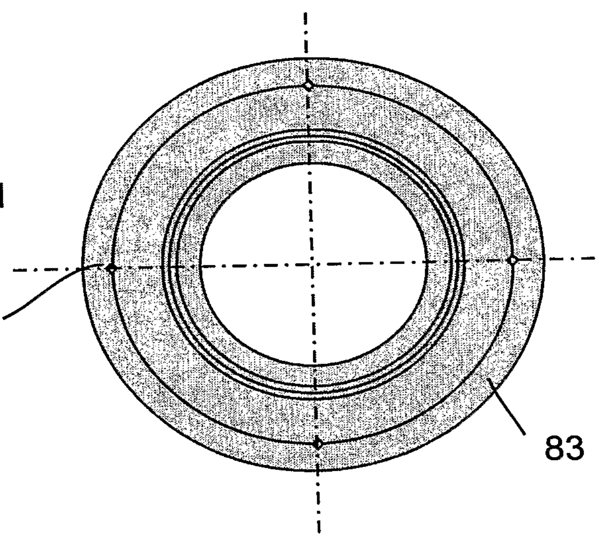

Figure 20

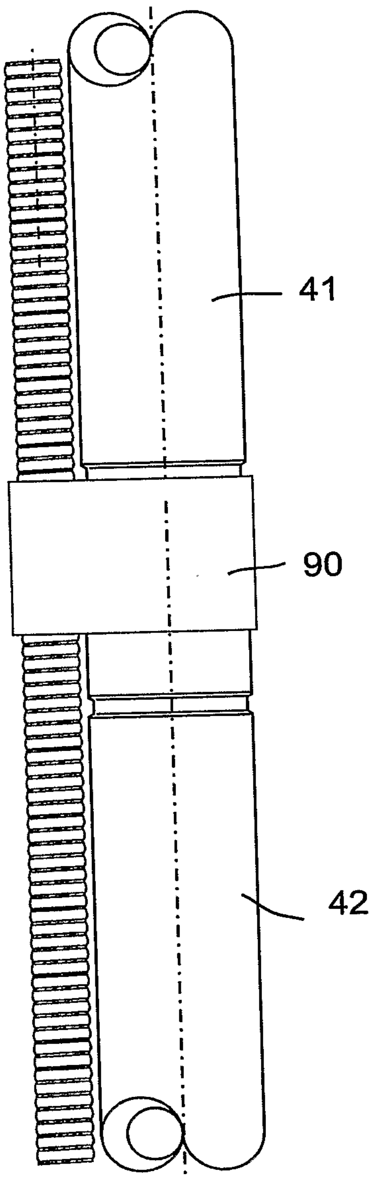

Figure 21

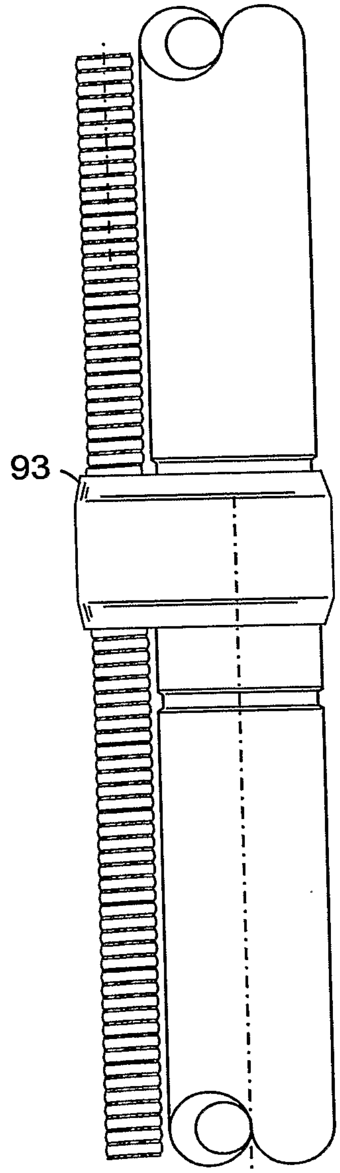

Figure 22

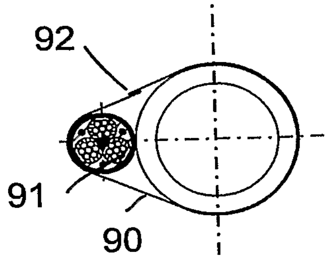

Figure 23

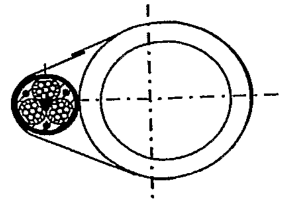

Figure 24

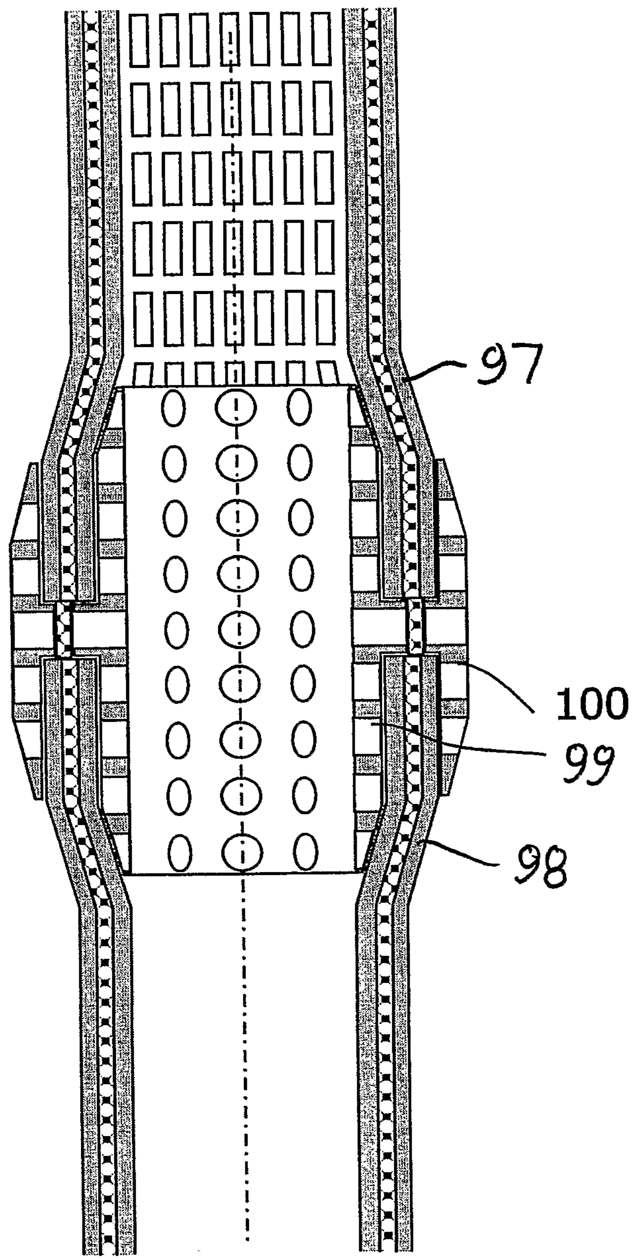

Figure 25

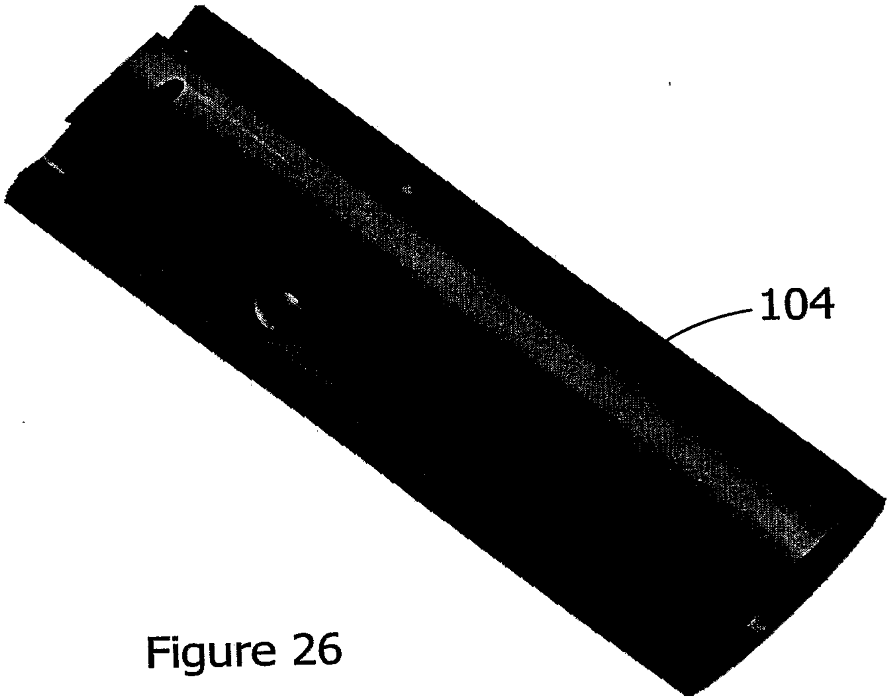

Figure 26

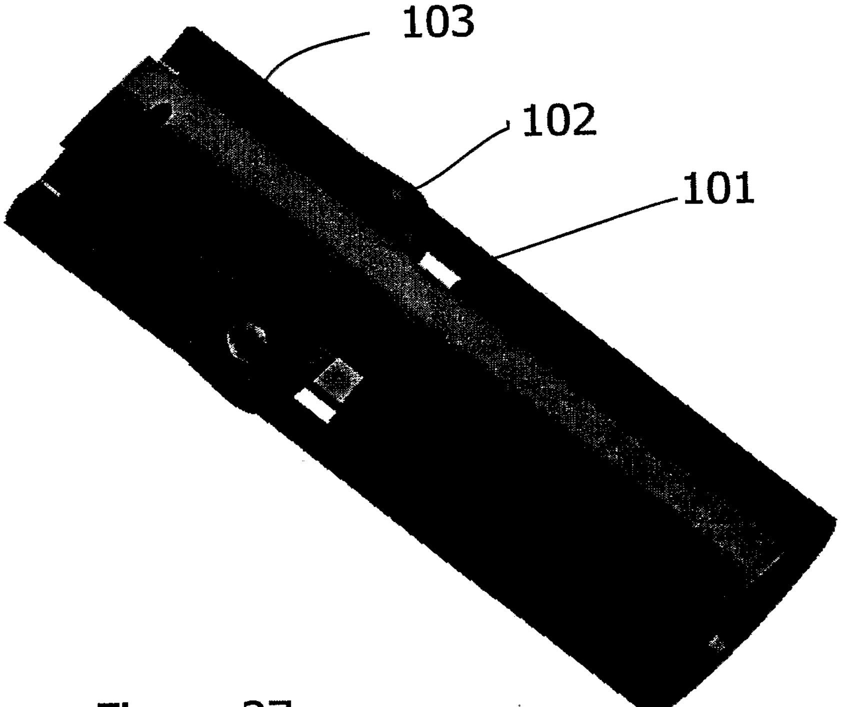

Figure 27

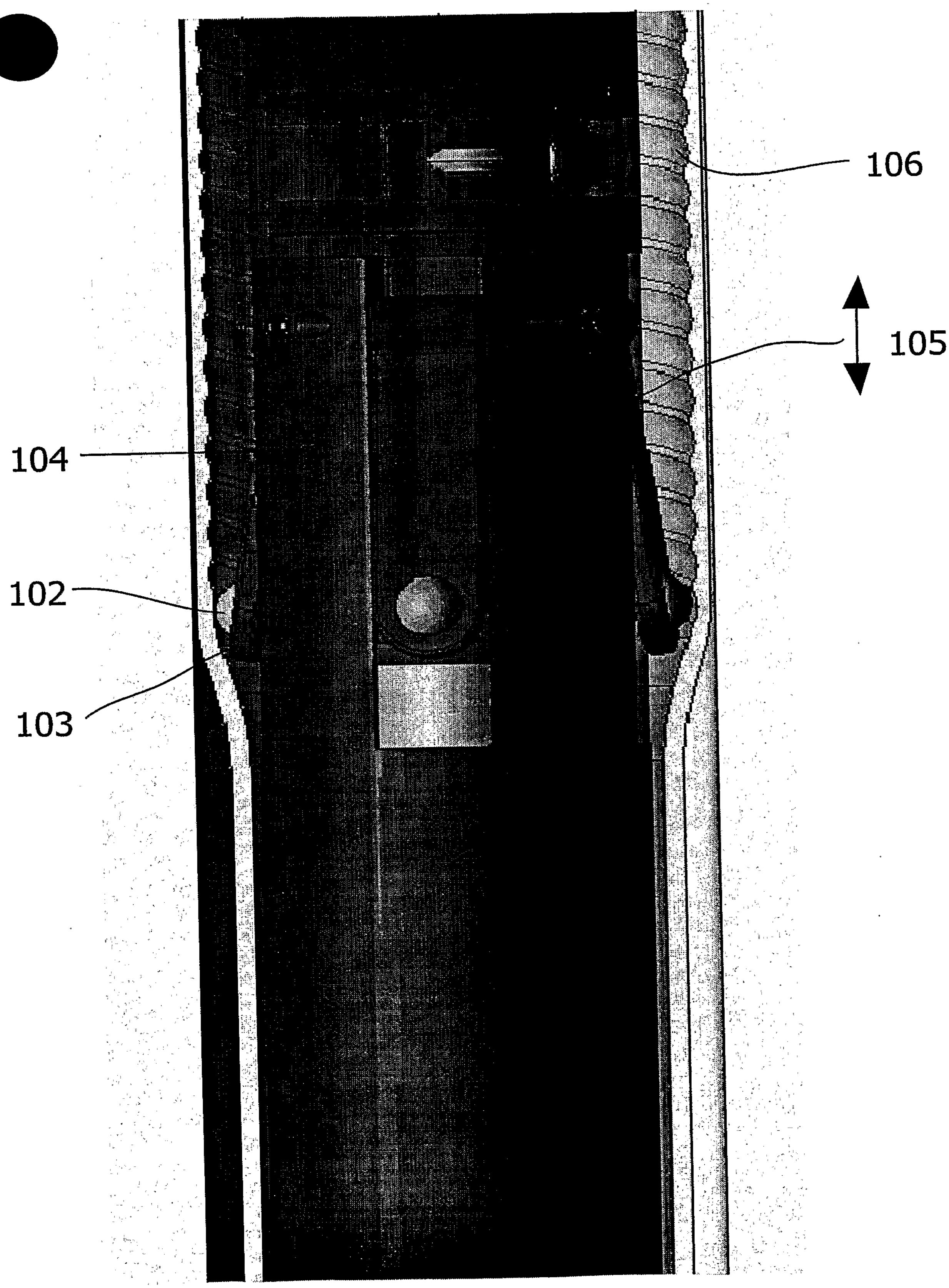

Figure 28

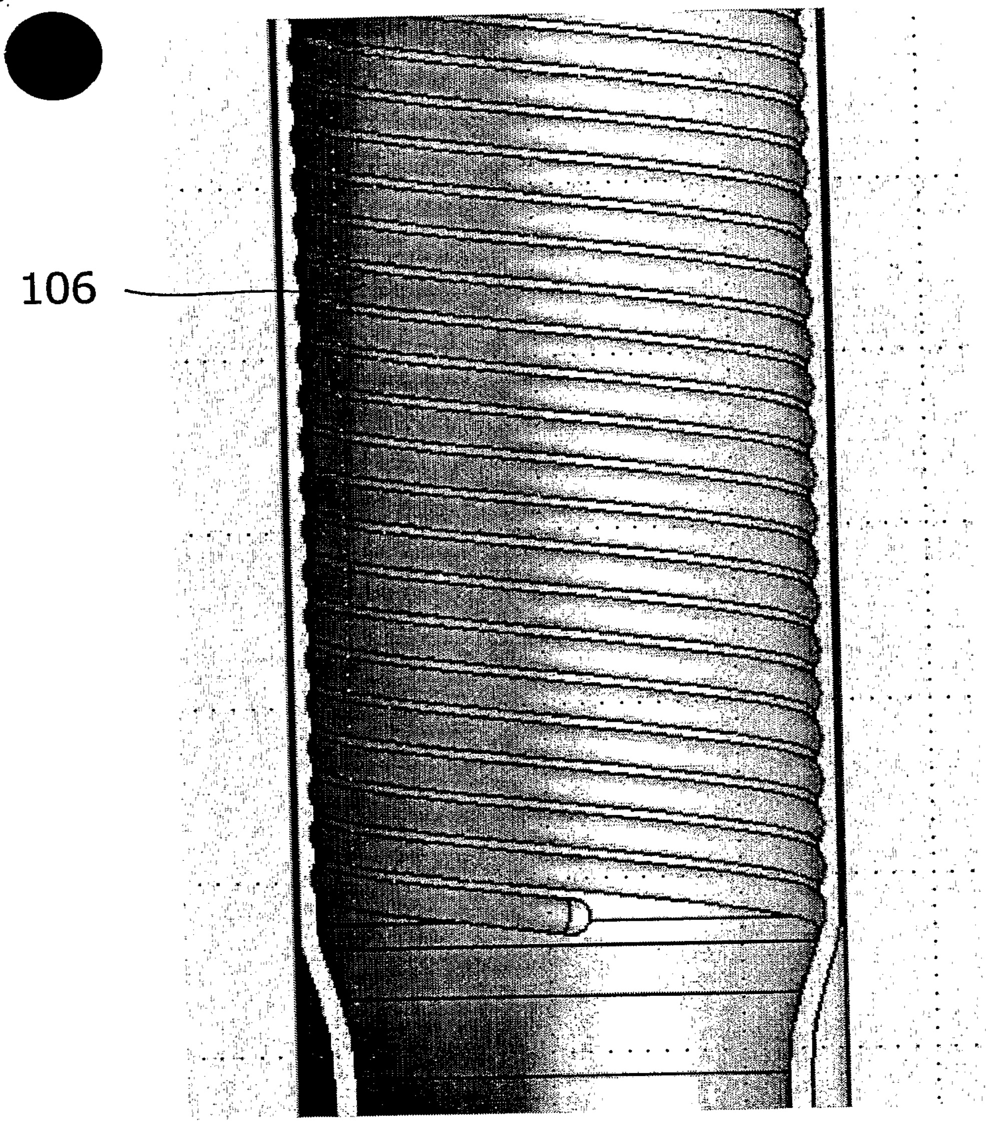

Figure 29

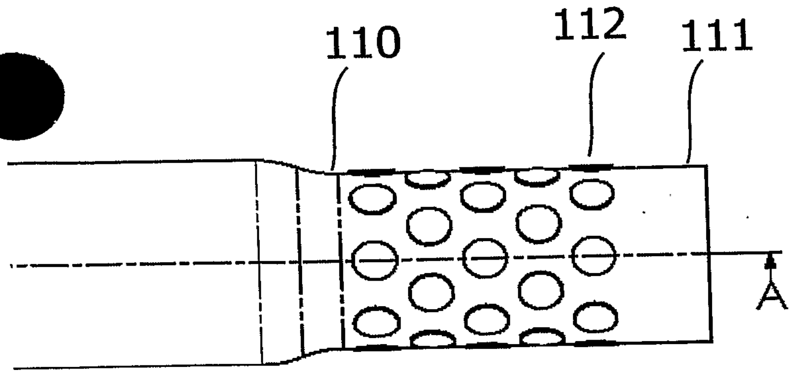

Figure 30

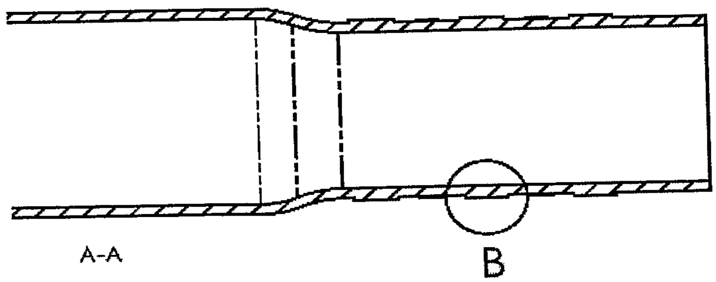

Figure 31

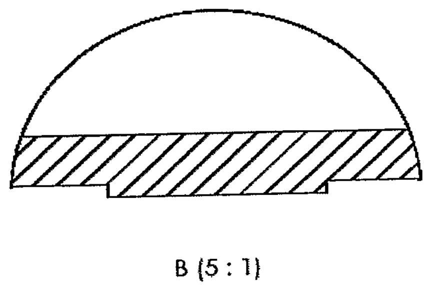

Figure 32

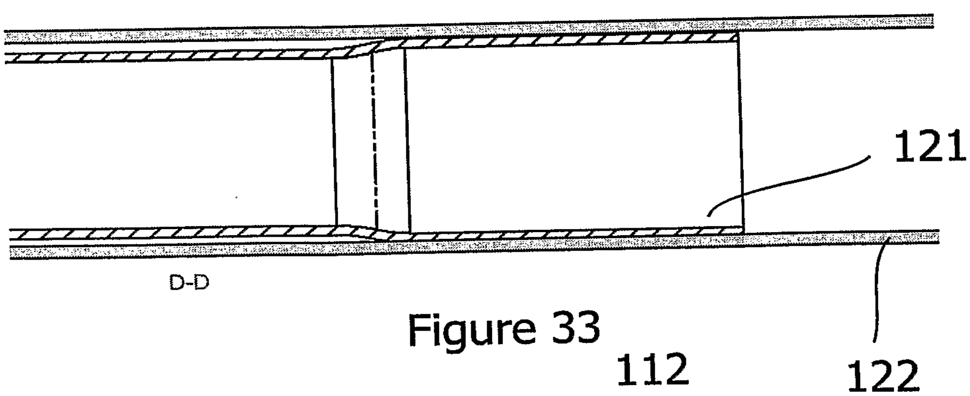

Figure 33

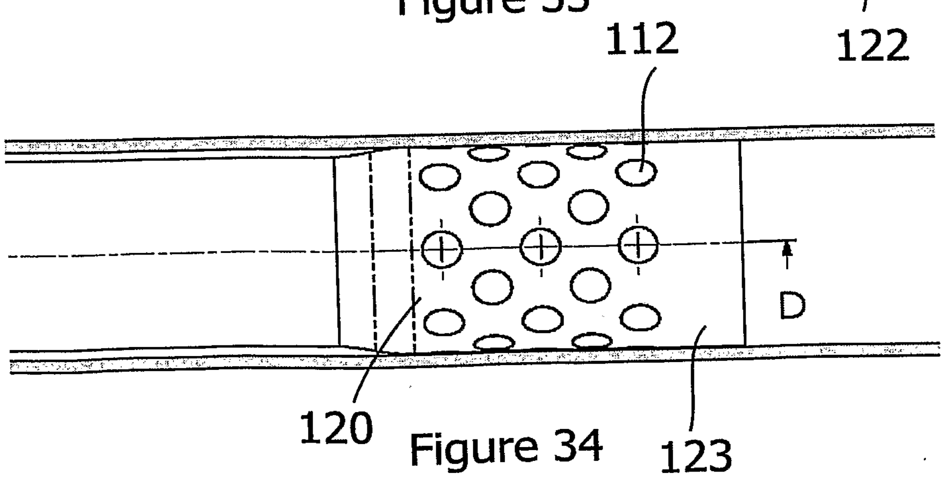

Figure 34

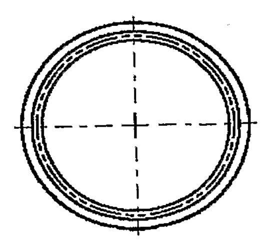

Figure 35

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